EOS PM-1

Mission Operations Concept Paper

Preliminary

REVISION E

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PREFACE

This paper documents the current operations concept for the EOS PM-1 spacecraft. The primary motivation for this document is to facilitate a consistent understanding of PM-1 operations concept by the entire PM-1 team: FOT, EOS PM-1 Project, spacecraft contractor, ESDIS Project, instrument teams, and science teams. It is expected that this paper, which presents a draft PM-1 operations concept, will be subject to revisions based upon further coordination and inputs by the PM-1 mission team. It is also expected that this paper will be a precursor to a PM-1 Operations Concept Document, where these concepts will be developed in greater detail.

It was not the intent of this paper to reinvent the wheel. Much work has been done on the generic operations concept for EOS. In particular, the ECS Operations Concept Part 2, FOS, and the EOS Mission Operations Concept Document both describe the generic operations concepts for EOS missions. This paper will focus on describing the PM-1 mission-specific implementation of generic EOS operations concepts. This paper will also develop in further detail those concepts which depend upon specific spacecraft and ground system capabilities in order to provide a long lead time for implementation or operations concept revision.

Please provide any comments concerning this paper to A. C. Kelly, NASA GSFC Code 505, (301) 614-5317, angie.kelly@gsfc.nasa.gov or Paul Hwang, NASA GSFC Code 422, (301) 286-6968, paul.hwang@gsfc.nasa.gov.

Reference Documents

- ECS Operations Concept for the ECS Project: Part 2, FOS, October 1995 (604-CD-004-001)
- 1995 EOS Reference Handbook
- EOS Ground System Architecture Description Document (GSFC ESDIS / Code 423)
- EOS Polar Ground Station Phase 2 Requirements Document, ESDIS Level 2 Requirements Volume 7 (Draft 1997)
- EOS Mission Operations Concept Document, September 1996 (GSFC ESDIS / Code 423)

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1.0 PM-1 MISSION OVERVIEW

The PM-1 mission is part of the Earth Observing System (EOS) multi-mission program to acquire the data necessary for the long-term study and understanding of Earth's global processes and systems. The PM-1 spacecraft is a 3-axis stabilized, self-contained free-flyer, operating in a near-circular sun-synchronous polar orbit at an altitude of approximately 706 km, with ascending node crossings at a spacecraft mean local time of 1:30 PM (+/- 15 minutes), and an orbital period of approximately 100 minutes. Nominal mission duration is 6 years (5 year design lifetime for spacecraft and instruments) and includes near-continuous nadir-pointing data collection.

The PM-1 mission is the first in a series of PM spacecraft whose major science objectives are the study of cloud formation, precipitation, radiative balance, terrestrial snow and sea ice, sea-surface temperature and ocean productivity. PM-2 and PM-3 follow-on missions will be launched 6 and 12 years after PM-1 launch in December 2000, respectively (TBD).

The following instruments fulfill the PM science objectives and are mounted onboard the PM-1 spacecraft:

ACRONYM	INSTRUMENT	INSTITUTION	COMPLEX?
AIRS	Atmospheric Infrared Sounder	JPL	No
AMSU-A	Advanced Microwave Sounding Unit - A	JPL	No
AMSR-E	Advanced Microwave Scanning Radiometer - EOS	Japan	No
CERES(2)	Clouds and Earth's Radiant Energy System	LaRC	No
GPS-R	Global Positioning System Receiver	GSFC	No
HSB	Humidity Sounder Brazil	INPE/Brazil	No
MODIS	Moderate-Resolution Imaging Spectrometer	GSFC	No

Note: A complex instrument requires frequent changes in its operating configuration (e.g. variable pointing).

The PM-1 spacecraft supports the above instruments by providing power, data services, thermal control, spacecraft pointing control, orbit maintenance propulsion, and space-to-ground communications.

The EOS Ground System (EGS) provides the PM-1 mission with communications, flight operations, science data processing, data archival, and data distribution. The EGS elements supporting the PM-1 mission include the EOS Data and Information System (EOSDIS), NASA Institutional Components (TDRSS, NCC, FDD), NOAA, and International Partner (IP) facilities (Brazil, Japan). Figure 1-1 provides a mission concept overview, including data flows for the PM-1 mission.

1.1 Operations Overview

PM-1 operations are highly autonomous. Science data are continuously collected in a nadir-pointing attitude maintained by the onboard flight software. Data generated by the instruments are stored on the SSR along with housekeeping data from the instruments and spacecraft for later downlink to a ground station. The EOS Polar Ground Stations will provide at least 1 ground station contact each orbit to support data downlink, spacecraft monitoring, and command uplinks.

The PM-1 mission will be operated from the multi-mission EOS Operations Center (EOC). Mission operations at the EOC include integrated planning and scheduling of the PM-1 spacecraft and instruments, generation of command loads for spacecraft and instrument control, and health and safety monitoring of the PM-1 spacecraft and all instruments. In addition, the EOC leads the coordination and scheduling of all EOSDIS elements, NASA institutional resources, and any other external participants for PM-1 mission operations support, and schedules ground station support for communications contacts.

The Instrument Operations Teams (IOTs) supports EOC instrument planning, instrument command load generation, and instrument status monitoring from remote locations using EOSDIS Instrument Support Toolkits (ISTs). The autonomous nature and routine operations requirements of the PM-1 mission and instruments minimize the need for high levels of real-time participation by the IOTs.

Reference the ECS Operations Concept Part 2, FOS, DID 604-CD-004-001, Section 3.4 Flight Ops Concept, for a more detailed description of the generic EOS flight operations concept. PM-1 specific operations concepts and mission implementation details are developed further in subsequent sections of this paper.

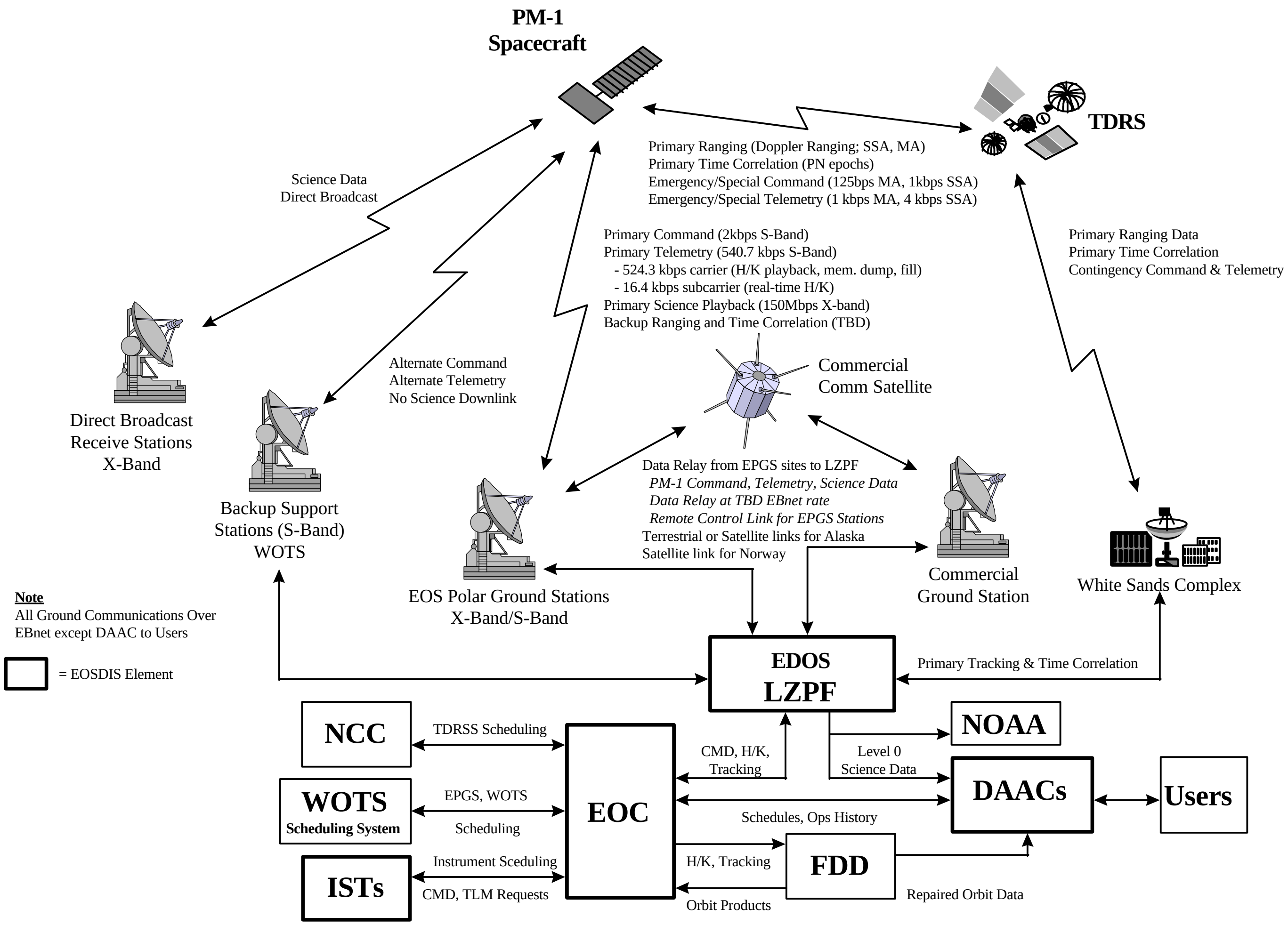

Figure 1-1 EOS PM-1 Operations Concept Overview

2.0 SPACECRAFT OPERATIONS

2.1 Multi-Mission Operations

The EOS Ground Segment (EGS) supports multiple EOS missions in various stages of development or operations simultaneously. The EOS AM-1 mission will be in the middle of its operational lifetime at the time of PM-1 launch, and before the termination of the PM-1 mission, the CHEM-1, LALT-1, AM-2, and PM-2 missions will begin on-orbit operations.

All EOS missions are operated by the EOS Flight Operations Team (FOT) out of the EOS Operations Center (EOC) at GSFC. Operations for all missions are performed primarily during the day shift, with off-shift support limited to executing pre-planned spacecraft contacts and monitoring mission status.

EOC staffing will transition from a full AM-1 team to a shared team for common functions with flight-specific or series-specific (AM, PM, LAM, CHEM) experts dedicated to each mission or series of missions. This builds expertise in critical spacecraft-specific and instrument-specific operations while reducing staff through shared generic functions where possible. Staffing levels for each mission will start out high during initial on-orbit checkout phases, and will be adjusted appropriately as operations are better understood and automated software is brought online and validated.

Contention for time-critical EGS resources is avoided through a ground system design which can process multiple spacecraft streams in parallel, and through coordinated orbit constellation design which minimizes simultaneous support requirements among several spacecraft. Each EOSDIS element in the real-time or near-real-time critical path will contain multiple processing strings to allow simultaneous operations with multiple spacecraft. For example, EDOS and the EOC are each designed to support simultaneous multi-mission operations through separate functional strings for each spacecraft.

Multi-mission contention for EPGS downlink support is illustrated in Figure 1-2. The EPGS ground stations will provide RF support to all EOS missions as well as Landsat-7 and EO-1. Figure 1-2 is based on the current EOS constellation design and assumes all spacecraft are downlinking to a single antenna at a single site. The constellation design was chosen to minimize overlapping coverage requirements and space missions according to total data volumes, allowing adequate time for retransmission of science data from EPGS to EDOS at GSFC without incurring delays. LALT-1 is not in a sun-synchronous orbit, and contact times will therefore shift compared to the rest of the spacecraft supported by the EPGS sites.

The current plans for EPGS implementation call for 2 antennas at Norway and 1 at Alaska. The multiple antennas relieve any concern for conflicting coverage between PM-1 and other missions, and provide good margins to support all current EOS mission communications requirements.

2.2 Communications Overview

The EOS Polar Ground Stations (EPGS) in Alaska and Norway will provide the normal communications link to all the EOS spacecraft, including PM-1. The PM-1 S-Band downlink provides real-time spacecraft and instrument housekeeping data, and the PM-1 X-band system supports high-rate playbacks of stored housekeeping and science data. PM-1 command uplink is via S-band. The Wallops Orbital Tracking Station (WOTS) provides contingency S-Band RF support for PM-1 and the other EOS missions.

Due to the highly inclined orbit of the PM-1 spacecraft and the northern location of both EPGS ground stations, coverage times will be nearly contiguous between the two stations. (reference Table A for station viewing periods and TABLE B for data volumes and downlink times).

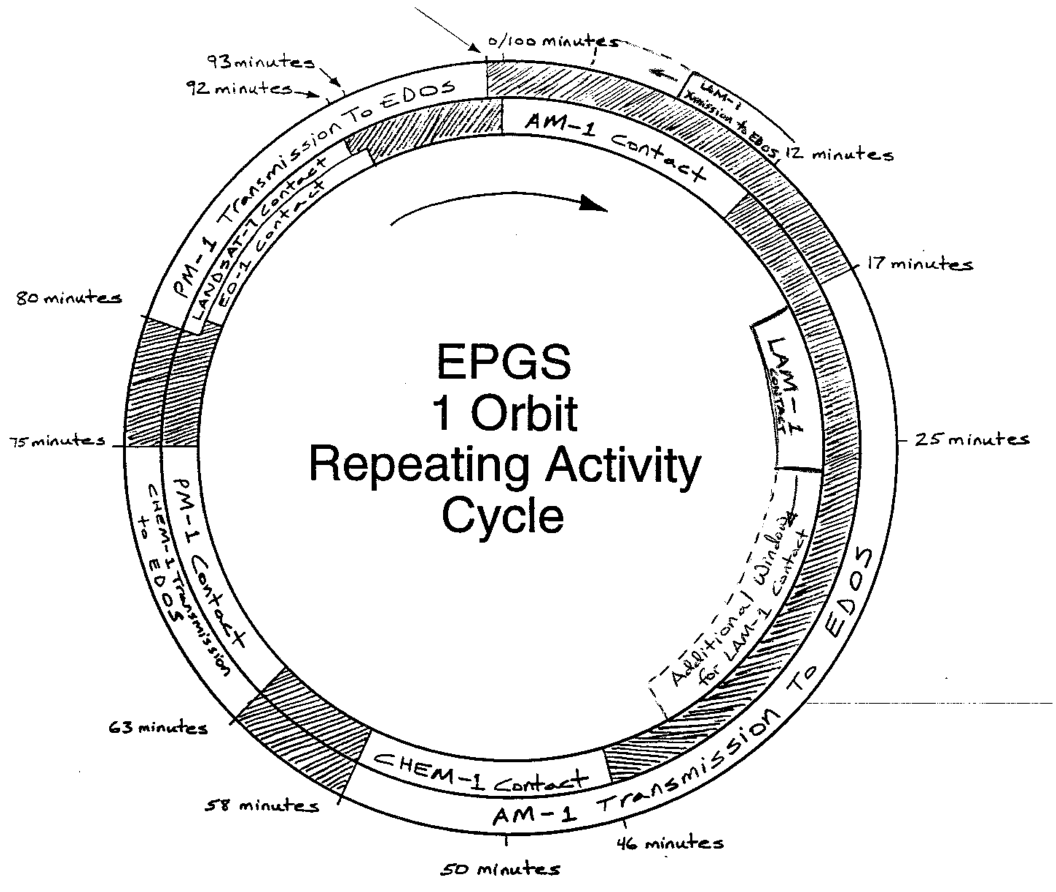

Figure 1-2 EPGS Repeating Orbit Activity Cycle

Notes

- All mission contact times (except LALT-1) are fixed relative to each other.
- LALT-1 contact time will shift due to its non-sun-synchronous orbit.
- Transmission times based upon mission data volumes and 45Mbps EBnet data rate.
- Diagram depicts contacts at a single ground station.
- Relative contact times based on latest EOS constellation design.

TABLE A: Typical Daily EPGN Coverage (5° minimum elevation, * = Primary)

	Norway	Alaska	Overlap	Gap	Total[2]
Orbit 1	11:35*	0	0	0	11:35
Orbit 2	11:42*	0	0	0	11:42
Orbit 3	11:33*	0	0	0	11:33
Orbit 4	11:29*	0	0	0	11:29
Orbit 5	11:36*	0	0	0	11:36
Orbit 6	11:42*	8:40	0:35	0	19:47
Orbit 7	11:22*	11:30	1:15	0	21:37
Orbit 8	10:19*	11:16	1:40	0	19:55
Orbit 9	8:24*	9:20	2:18	0	15:26
Orbit 10	5:56	7:19*	3:50	0	9:25
Orbit 11	4:19	7:34*	4:19	0	7:34
Orbit 12	5:36	9:43*	2:02	0	13:17
Orbit 13	8:05	11:26*	1:05	0	18:26
Orbit 14	10:07	11:17*	0:27	0	20:57
Orbit 15	11:17	7:40*	0:00	0:39	18:57
Total	145:02	95:45	17:31		223:26
Average	9:40	9:34[1]			14:53

Note 1: Orbits with no Alaska contact are not included in Alaska average calculation. Alaska average for all orbits is 6:23.
Note 2: Total adds orbital coverage times for Alaska and Norway, and subtracts overlap.

TABLE B: Data Volumes & Downlink Time

PM-1 Instrument	**Data Rate (kbps)**
AIRS	1270.00
AMSU	3.20
CERES-1	10.00
CERES-2	10.00
GPS-R	TBD
HSB	4.20
AMSR	130.00
MODIS	6100.00
S/C H/K	16.00
Total Rate (kbps)	7543.40
Including 15% Overhead	8674.9
Gbits Per Orbit	52.0
150Mbps X-BD Dnlk Time	5:47

One contact per orbit will nominally be scheduled from the available ground station passes to support PM-1 operations. Additional contacts will be scheduled as required to support contingency operations or periodic normal operations which require additional coverage. Reference Figure 1-3 for a typical PM-1 pass plan. The onboard solid state recorder (SSR) will have a capacity of at least 15 Gbits. This gives the SSR 18 hours of capacity at the current instrument and spacecraft data rates (reference Table B), providing the flexibility to reduce coverage without losing science data.

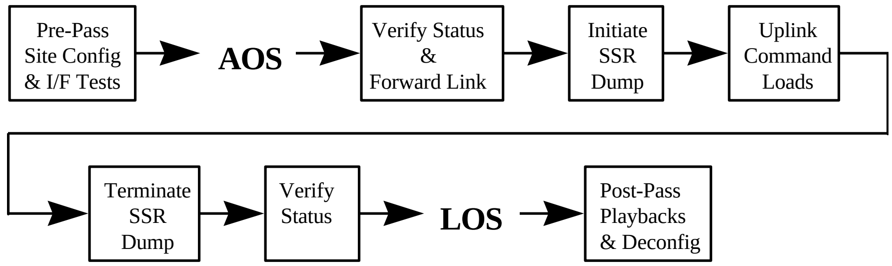

Figure 1-3 Nominal EOS PM-1 Pass Plan

2.3 Health & Safety Monitoring

The EOC will be responsible for PM-1 spacecraft and instrument health & safety monitoring in real-time, and will respond to time-critical anomalies using pre-approved procedures. During the off-shift, a small shared team monitors the status of all EOS spacecraft, and pages specific spacecraft experts if a critical anomaly occurs.

The EOC has two nominal sources for PM-1 health & safety data:

- Real-time housekeeping data each orbit (~10 minutes) via EPGS S-band link
- SSR recorded housekeeping data dumped each contact via EPGS X-band link

Real-Time Housekeeping Data

The S-band downlink is composed of a 524kbps carrier and a 16kbps subcarrier. Real-time housekeeping data is downlinked on the subcarrier. The carrier channel normally contains fill data, but it can be used for housekeeping playbacks and memory dumps. The EPGS ground station forwards the entire S-Band downlink (separate streams for carrier and sub-carrier) to EDOS via a commercial satellite or terrestrial link in real-time (WOTS sends only the 16kbps real-time stream to EDOS in real-time). EDOS identifies the real-time data by VCID and forwards the stream to the EOC for real-time command control and status monitoring. Real-time data received at the EOC is automatically processed by limit-checking and rules-based software to verify nominal spacecraft and instrument status. Time-critical anomalies will cause an alert, and the PM-1 Spacecraft Evaluator will respond using approved procedures. Real-time data also provides the Command Link Control Words (CLCWs) required to support CCSDS COP-1 command processing.

Playback Housekeeping Data

Playback housekeeping data is nominally dumped from the SSR with the science data on the 150Mbps X-band downlink. A full day’s worth of recorded housekeeping data (at 16kbps continuous rate) will take approximately 10 seconds to downlink at 150Mbps. The SSR playback is performed in priority order, with housekeeping data dumped first to support health & safety monitoring. Spacecraft housekeeping and science data will continue to be recorded onboard during any playbacks.

The X-band dump recorded at the ground station is forwarded to EDOS (in the order received from the spacecraft) over a high rate commercial satellite or terrestrial link immediately after the real-time contact is terminated. The nominal 52Gbit SSR dump (performed each orbit) will take 28 minutes to play back to EDOS at an EBnet rate of 31Mbps. The dumps include both instrument science data and housekeeping data for the last orbit.

In a contingency mode, recorded housekeeping data can be dumped from the SSR via a high-rate S-Band carrier downlink (524kbps). This mode will be used when the X-band is not available or when performing contacts with the WOTS contingency ground station (which is not required to support X-band dumps from EOS spacecraft). 16kbps real-time data will be modulated on the subcarrier of the same link, so a total data rate of 540kbps (carrier + subcarrier) is downlinked to the ground stations in this mode. The EPGS ground station forwards the entire S-Band downlink (separate streams for carrier and sub-carrier) to EDOS in real-time (WOTS sends only the 16kbps real-time stream to EDOS in real-time, with playback data sent post-pass).

Playback housekeeping data is identified by virtual channel ID at EDOS, stripped out, and sent to the EOC in near-real-time (any fill data is discarded at EDOS). EDOS also compiles a level-zero housekeeping data set, and transfers this data set to the GSFC DAAC for permanent storage.

Upon receipt from EDOS, playback housekeeping data is automatically run through automated limit-checking software, rule-based software monitoring routines, statistical checks, and other software tools at the EOC to verify nominal operation of the spacecraft and instruments. Indicated violations cause alerts and are investigated by the PM-1 Spacecraft Evaluator, and appropriate actions are recommended to the PM-1 Operations Controller.

Housekeeping Data via IST

Instrument housekeeping data will be available to the instrument teams through the ISTs. The instrument teams will perform long-term trending and instrument health analysis at their home facilities. Instrument teams may provide inputs and make inquiries to the PM-1 Spacecraft Evaluator concerning instrument health & safety at any time. Instrument teams are the source for all instrument limits, rules, and response procedures used by the PM-1 Spacecraft Evaluator for instrument monitoring at the EOC.

Memory Dumps

When a memory dump is required, it is commanded in real-time and downlinked via the S-band link to an EPGS or WOTS ground station. PM-1 processor memory dumps are downlinked at a rate of 64kbps over the 524kbps S-Band carrier channel (fill data is inserted in the unused bandwidth). Memory dump data is identified by VCID or APID at EDOS, and forwarded to the EOC for analysis in near-real-time.

Sustaining Engineering

Sustaining engineering concepts for the PM-1 mission will follow the generic EOS mission concept. Spacecraft trending, analysis, and calibrations will be performed by the EOC FOT, with support from FDD and the spacecraft contractor as required. SDVF will provide PM-1 spacecraft flight software maintenance. Instrument sustaining engineering, including all calibrations and flight software updates, will be provided for by the IOTs, who will have access to all instrument and spacecraft data via IST interfaces to the EOC. The EOC FOT may support IOT instrument sustaining engineering functions by performing routine trending and analysis as defined by each of the IOTs for their respective instruments.

Instrument Health & Safety Monitoring

The EOC has primary responsibility to perform time-critical health & safety monitoring of the PM-1 spacecraft and instrument. The EOC will monitor instrument status using real-time and back-orbit housekeeping data downlinked to the EPGS ground stations. Data is transferred to the EOC via EDOS for automated limit and rules processing. Alerts and pages will notify the Spacecraft Evaluator of anomalies discovered by the software. Premission, the IOTs will develop limit sets, rules, and standard anomaly response procedures for use by the EOC for maintaining the health & safety of each instrument.

The PM-1 IOTs have near-real-time access to all instrument (and spacecraft) housekeeping and engineering data through remote login to the EOC via their ISTs. This data will be used primarily to support instrument sustaining engineering functions in an offline mode. However, in contingency situations or during checkout activities, instrument teams may use the data to participate in health & safety monitoring activities.

2.4 *Integrated Mission Planning*

The PM-1 mission will follow the generic mission planning and scheduling concepts developed for EOS missions. All mission planning and scheduling activities for PM-1 will be performed at the EOC during the day shift, 7 days per week.

Long-Term Mission Planning

The Instrument Working Groups (IWGs) and project scientist will define instrument goals and objectives pre-mission, as well as a Baseline Activity Profile (BAP) for the each instrument. The EOC will maintain the instrument BAPs, and develop and maintain a spacecraft subsystem BAP for routine spacecraft operations. The integrated BAP will define operations and data collection requirements to the extent necessary for EOC schedulers to determine orbital recorder data volumes and to produce daily detailed activity schedules for the instruments and spacecraft.

Initial Weekly Scheduling

Weekly scheduling is performed by the EOC PM-1 Spacecraft Scheduler. Deviations from instrument BAPs are submitted by the EOC instrument scheduler to the PM-1 spacecraft scheduler via the IST interface. Instrument schedulers coordinate with the EOC instrument scheduler to generate deviation inputs. Spacecraft BAP deviations are submitted by the EOC PM-1 spacecraft engineering personnel. Using the instrument BAPs, submitted instrument deviations, and spacecraft BAP with required spacecraft deviations, the PM-1 spacecraft scheduler generates and validates the required resource profile for the target week. Based on these generated resource profiles, predicted groundstation coverage times, and spacecraft resource availability, the EOC Spacecraft Scheduler validates that the resource profile does not exceed capabilities at any time during the week. Negative margin on resources is resolved as part of the initial scheduling process through coordination with instrument schedulers, IOTs, spacecraft schedulers, and ground station personnel. All initial scheduling products will be available for review by IOTs via their ISTs.

As part of initial scheduling, the EOC will coordinate with Wallops for scheduling of the EPGS ground stations. Normally, the PM-1 mission will be supported by an EPGS contact on every orbit (Norway or Alaska). Data routing at the EDOS will determine which site commands are routed to and which site's acquired real-time data will be sent to the EOC (TBD). Additional ground station contacts will be scheduled as required to support off-nominal operations.

The scheduling of WOTS for PM-1 contingency pass support will occur as part of initial scheduling. The EOC will use the same Wallops interface for the scheduling of WOTS and EPGS for PM-1 support.

Initial weekly scheduling will also include the scheduling of nominal TDRSS support via the NCC. The EOC will send weekly scheduling requests to the NCC for tracking contacts (5 minutes per orbit for at least 10 orbits per day), orbit maneuver burn support, and other special operations support.

Final Scheduling

Final scheduling consists of generating an integrated spacecraft/instrument detailed activity schedule. Schedules are generated by the EOC spacecraft scheduler based upon BAPs, BAP deviations for the spacecraft and instrument, and ground station contact times. Detailed activity schedules are distributed for review to the EOC PM-1 engineering personnel and IOTs via IST terminals. The detailed activity schedule is then validated using resource constraint algorithms, and any final conflicts resolved. Integrated command loads are built automatically by the Command Management System (CMS) based upon the detailed activity schedule and pass plans (including real-time commands) are generated at the EOC and validated using FOS tools. EPGS ground stations are notified of primary/secondary support status and predicted playback times as part of the final scheduling process. Reference section 2.2 (Command Operations) for further commanding details. Late changes and TOOs are implemented through the uplink of new command loads to replace those already onboard. These new loads are validated on the ground before uplink to ensure that resource constraints will not be violated by the new changes.

Instrument Mission Planning & Command Inputs

For the PM-1 mission, all real-time commands and command loads for both the spacecraft and instruments are built, validated, and transmitted from the EOC based on pre-mission developed instrument Baseline Activity Profiles (BAPs) and instrument command and telemetry databases. The PM-1 IOTs makes inputs for revisions to their instrument BAPs or databases as required during the course of the PM-1 mission. The databases and BAPs for all instruments (and spacecraft) are maintained by the FOT at the GSFC EOC.

The lead scheduler for each IOT collects inputs from the entire instrument team, and provides coordinated inputs to the EOC for mission planning and operations for their instrument. Inputs may include instrument mode changes, calibrations, or individual command requests as required. All PM-1 IOTs have access to the latest planning products and schedules via their ISTs. The lead scheduler for each instrument may contact the PM-1 Instrument Scheduler at the EOC at any time to request information or provide an input.

During instrument checkout or instrument anomaly resolution, the instrument teams may be remotely connected via their ISTs to review data and make real-time command requests to the EOC through their IST.

2.4 Command Operations

All spacecraft and instrument command loads are sent from the EOC by the PM-1 Command Activity Controller during the day shift. Stored command loads for the instrument and spacecraft are uplinked to allow adequate time for verification and re-uplink, if required. While specific commanding requirements have not yet been determined, it is expected that a typical 10 minute EPGS contact will provide adequate time for the daily command load uplink requirements at 2kbps. PM-1 stored command loads are expected to cover routine onboard commanding requirements for at least 24 hours.

Command loads and real-time commands are generated at the EOC using the command management system and spacecraft and instrument command databases maintained at the EOC. Instrument command loads are generated at the EOC based upon IOT BAPs and IOT-submitted deviations. Similarly, spacecraft subsystem command loads are generated at the EOC based upon the spacecraft BAP and subsystem engineer-submitted deviations. Flight software patches, if required, will be generated and validated by the IOTs (for the instruments) or by the GSFC Software Development and Validation Facility (SDVF) (for the spacecraft). The FDD system will generate state vector updates for uplink and command loads for periodic orbit maintenance maneuvers. All of the various command inputs are integrated into pass plans by the PM-1 Command Activity Controller during the final scheduling phase.

Commanding is performed during real-time contacts with the spacecraft through the EPGS ground stations. Commanding is executed by the PM-1 Command Activity Controller at the EOC with pre-built pass plans, and real-time telemetry is used to verify a good link before uplink begins. Commands sent from the EOC are transmitted in real-time over the EBnet to EDOS, and throughput from EDOS to the appropriate ground station for uplink at 2kbps. The CCSDS Command Operations Procedure 1 (COP-1) is executed over the spacecraft-to-EOC real-time link, and ensures that commands get onboard without errors and in the proper order. Successful commanding is also confirmed by CRC checks, stored command table memory dumps, and housekeeping telemetry verifications.

EOC pass plans (also known as ground scripts) which control command uplinks will run automatically, and will be monitored by the PM-1 CAC. Failure of automatic pass plan execution will be handled by manual execution. The use of automated pass plans for the PM-1 mission will rely on successful development and verification of this capability during the AM-1 mission, and will be implemented following successful verification during the PM-1 activation and checkout period. Note that pass plans include pre-pass network and ground station configuration verifications, as well as real-time commanding and command load uplinks.

In addition to the command loads (stored commands, ephemeris updates, tables, flight software patches) nominally uplinked once per day or less, real-time commanding will be required on each scheduled pass in order to dump the solid state recorder (SSR), perform memory load and dump control, and perform spacecraft system reconfigurations (as required). All science and housekeeping data is recorded on the SSR. EOC pass plans control all real-time commanding.

2.6 Tracking & Flight Dynamics Support

All routine orbit determination, propagation, and planning aid generation activities will be performed on FDD-provided systems at the EOC by EOC planning and scheduling personnel. FDD support will provide maneuver planning, calibration support, performance analysis, and consulting to PM-1 and other EOS missions as required. All flight dynamics support is performed during the day shift.

Orbit Determination

Tracking data will be obtained using TDRSS MA two-way coherent tracking contacts, with data routed from the WSGT through EDOS to the EOC FDD systems in near-real-time. Tracking contacts will be scheduled through the NCC for 5 minutes of MA time per orbit for at least 10 orbits per day. The EOC will use propagated PM-1 orbits to schedule MA tracking contacts with the NCC in weekly blocks as part of *Initial Scheduling.* Passes will be scheduled around ground station contacts and within TDRS MA viewing periods as determined by FDD-provided software tools.

Tracking data from WSGT is processed on the FDD-provided systems to generate updated spacecraft ephemerides. EPGS ground station tracking data can also be used as a backup or to provide additional data for orbit determination (TBD). Predicted orbit data is generated by the FDD system at the EOC and uplinked daily to the spacecraft. FDD will generate definitive orbit calculations from all available tracking data to support science processing in non-real-time. Definitive orbit data is provided to the DAACs from FDD. The EOC FDD system will also propagate PM-1 orbit solutions for mission planning and scheduling purposes, and perform all required constraint verification and orbital event generation.

Onboard State Vector Maintenance

The PM-1 spacecraft uses tables of predicted orbits uplinked daily from the EOC for all onboard orbit knowledge requirements. There is no onboard orbit propagation or orbit determination capability.

Spacecraft Clock Correlation

The method used for onboard clock error determination and update is TBD. Both TDRSS and EPGS options are available. The leading contender for clock correlation is the TDRS PN epoch method during tracking contacts. Frequency determination can also be accomplished via TDRS, but using non-tracking one-way non-coherent contacts. Backup clock correlation methods via EPGS ground stations are under investigation.

Orbit Maintenance

Periodic orbit maneuvers will be required to maintain the PM-1 spacecraft orbit within requirements. FDD will provide maneuver planning support to the EOC. TDRS SSA or MA coverage will be scheduled during all orbit maneuver burns to provide a real-time command and telemetry link to the spacecraft during these critical operations.

2.7 Instrument-Specific Operations Information

(TO BE DEVELOPED FURTHER BY THE PM-1 INSTRUMENT AND SCIENCE TEAMS)

This section will include specific information concerning the unique aspects of operations of the PM-1 instruments. Included will be overviews of operations, commanding requirements, IST and ICC plans, real-time and offline monitoring and analysis responsibilities, scheduling and planning interfaces.

2.8 Special & Contingency Operations

(TO BE DEVELOPED FURTHER BY THE PM-1 INSTRUMENT AND SCIENCE TEAMS)

PM-specific details for the special operations listed below have not yet been developed, but are expected to follow closely with the concepts used for the EOS AM-1 mission. Both the spacecraft contractor and instrument teams will support launch, early orbit, activation, and checkout periods, with various teams leading their portion of the operations during these phases, and handing over to the FOT for nominal operations. Prelaunch integration and testing will include interface testing, string and end-to-end testing, acceptance testing, operations simulations, and final readiness testing.

Prelaunch Integration & Test Operations Concepts

Launch & Early Orbit (Activation & Checkout Period)

Anomaly Resolution

3.0 SCIENCE OPERATIONS

(TO BE DEVELOPED FURTHER BY THE PM-1 INSTRUMENT AND SCIENCE TEAMS)

3.1 Science Data Acquisition

Science data from each PM-1 instrument is stored onboard the PM-1 spacecraft in the SSR. The SSR is partitioned into areas for each instrument and spacecraft housekeeping, and CCSDS virtual channel downlinks (one virtual channel for each instrument on the 150Mbps X-band link) simplifies prioritized ground processing and data routing at EDOS. Each orbit, the SSR is dumped via a 150Mbps X-band downlink to one of the EPGS ground stations in Alaska or Norway. The data recorded on the SSR is dumped in priority order. The SSR will have a capacity of at least 136Gbits, providing ~2.6 orbits of recording capacity based on expected PM-1 instrument data rates (reference Table B in Section 2.2). An orbit's worth of science data will take approximately 5 minutes 47 seconds to downlink via the X-band link, and an average of almost 15 minutes is available each orbit through combined coverage from the EPGN ground stations. A full recorder will take 15 minutes to dump via the X-band link, and will require at least two station contacts and possibly multiple orbits to provide sufficient coverage.

Data acquired at the ground stations is recorded and forwarded to EDOS at a rate of at least 31Mbps. The first data down (highest priority) is forwarded first. The 1-orbit playback should be complete within 28 minutes of the end of the ground station passes for each orbit. EDOS performs level zero processing of the science data, and forwards the data to the appropriate DAAC for further processing, archival, and distribution. (Note that a playback of a full recorder (136Gbits) will take 73 minutes to playback to EDOS over a 31Mbps link).

The EDOS also forwards instrument data to NOAA after minimal processing. NOAA science data will be the first played back and first priority for processing at EDOS after back-orbit housekeeping data for the EOC. NOAA instrument data requirements are still being developed, but initial requirements indicate that AIRS data is of the highest priority, followed by MODIS, AMSU, and HSB data, with CERES data having the lowest NOAA priority. The following listing shows some of the delay factors for data delivery to NOAA for AIRS data alone, and for all instrument data. These calculations assume a nominal 1-orbit data dump.

- 100 minute orbit
- 05:47 X-Band science/housekeeping dump
- 28 minute EPGN playback to EDOS (~4 minutes for housekeeping + AIRS data)*
- EDOS LZPF processing delay TBD
- 169 second 45Mbps T3 transfer to NOAA for 1 orbit's worth of AIRS data (16.7 minutes for all data)

*Priority-ordered SSR dumps allow highest priority data to be played back first

3.2 Science Data Processing

EDOS performs level zero science data processing on all instrument and spacecraft data. Processing is accomplished in priority order, based on direction from the EOC. Generally, housekeeping data from the spacecraft and instruments is processed first, followed by NOAA data priorities, and then the other instruments. Level zero science data from each instrument is then forwarded over the EBnet to the appropriate DAAC for further processing and the generation of science data products and metadata. Spacecraft and instrument back-orbit housekeeping data are forwarded to the EOC for health & safety analysis. Note that NOAA data may be stripped out and sent from EDOS prior to full level zero processing. However, level zero processing of all instrument data will be completed by EDOS before it is transferred to the appropriate DAAC.

3.3 Science Data Archive & Distribution

Science data archive and distribution is performed by the EOSDIS DAACs.

ACRONYM LIST

ACS	Attitude Control System
AI	Artificial Intelligence
AIRS	Atmospheric Infrared Sounder
AM	EOS AM Mission
AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
ASAP	As Soon As Possible
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BAP	Baseline Activity Profile
BD	Band
CAC	Command Activity Controller
CCSDS	Consultive Committee for Space Data Standards
CERES	Clouds & Earth's Radiant Energy System
CHEM	EOS Chemistry Mission
CMD	Command
CMS	Command Management System
CRC	Cyclic Redundancy Check
DAAC	Distributed Active Archive Center
EBNET	EOSDIS Backbone Network
EDOS	EOS Data and Operations System
EGS	EOS Ground System
EOC	EOS Operations Center
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
EPGN	EOS Polar Ground Newtork
FDD	Flight Dynamics Division
FIDR	Failure Detection, Isolation, Recovery
FOS	Flight Operations System
FOT	Flight Operations Team
FS	Slight Software
FWD	Forward
Gbit	Gigabit
H/K	Housekeeping
HSB	Humidity Sounder Brazil
ID	Indentifier or Identification
IOT	Unstrument Operations Team
IST	Instrument Support Toolkit
IWG	Instrument Working Group
KBPS	Kilobits Per Second
KM	Kilometer
LALT	EOS Laser Altimeter Mission
LEO	Low Earth Orbit
MA	Multiple Access
MBPS	Megabits Per Second
MGA	Medium Gain Antenna
MIN	Minutes
MODIS	Moderate Resolution Imaging Spectromter
NCC	Network Control Center
NOAA	National Oceanic & Atmospheric Administration
PM	EOS PM Mission
PN	Pseudo-Random Noise
RF	Radio Frequency
RTCS	Relative Time Command Sequence
RTN	Return
SCF	Science Computing Facility
SDVF	SoftwareDevelopment & Verification Facility
SSA	S-band Single Access
SSR	Solid State Recorder
TBD	To Be Determined
TDRS	Tracking & Data Relay Satellite
TDRSS	Tracking & Data Relay Satellite System
TLM	Telemetry
TMON	Telemetry Monitor
TOO	Targets Of Opportunity
WOTS	Wallops Orbital Tracking Station